

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY) 05-04-2012		2. REPORT TYPE MASTER OF MILITARY STUDIES RESEARCH PAPER		3. DATES COVERED (From - To) SEP 2011 - APR 2012	
4. TITLE AND SUBTITLE  LEVERAGING SCIENCE & TECHNOLOGY TO IMPROVE LOGISTICS AND MAINTAIN COMBAT EFFECTIVENESS				5a. CONTRACT NUMBER N/A	
				5b. GRANT NUMBER N/A	
				5c. PROGRAM ELEMENT NUMBER N/A	
6. AUTHOR(S)  MELISSA D. CHESTNUT, MAJ, USMC				5d. PROJECT NUMBER N/A	
				5e. TASK NUMBER N/A	
				5f. WORK UNIT NUMBER N/A	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Command and Staff College Marine Corps University 2076 South Street Marine Corps Combat Development Command Quantico, Virginia 22134-5068				8. PERFORMING ORGANIZATION REPORT NUMBER  N/A	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)  N/A				10. SPONSOR/MONITOR'S ACRONYM(S)  N/A	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)  N/A	
12. DISTRIBUTION / AVAILABILITY STATEMENT  Distribution Statement A: Approved for public release; Distribution is unlimited.					
13. SUPPLEMENTARY NOTES  N/A					
14. ABSTRACT  The changing global security environment, impending fiscal constraints and the requirement for the US military to maintain combat effectiveness has resulted in logistical limitations at the operational and tactical levels. The US military must be able to fight any type of conflict (e.g., conventional or unconventional), and the requisite support must be available to maintain these forces. As logistics systems are developed, science and technology must be leveraged to sustain combat forces regardless of the type of contingency, terrain and dispersion of forces. Automated Identification Technology provides the commander with the ability to track the location of supplies on the battlefield. Sense and Respond Logistics ensures the commander only receives needed supplies at the right time. An integrated logistics system links logistical requirements at the component level and supports the commander in the decision-making process. The unmanned logistics systems have the added benefit of minimizing casualties and eventually reducing costs. These important technological advances in logistical systems will effectively support any future contingency and maintain combat effectiveness, while still reducing costs and minimizing US casualties.					
15. SUBJECT TERMS  Future Logistics Systems, Advancements in Logistics, Unmanned Logistics Systems, Automated Identification Technology, Sense and Respond Logistics					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT  UU	18. NUMBER OF PAGES  43	19a. NAME OF RESPONSIBLE PERSON MARINE CORPS UNIVERSITY/CSC
a. REPORT UNCLAS	b. ABSTRACT UNCLAS	c. THIS PAGE UNCLAS			19b. TELEPHONE NUMBER (include area code) 703-784-3330 (ADMIN OFFICE)

*United States Marine Corps  
Command and Staff College  
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2076 South Street  
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Quantico, Virginia 22134-5068*

MASTER OF MILITARY STUDIES

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**LEVERAGING SCIENCE & TECHNOLOGY TO IMPROVE  
LOGISTICS AND MAINTAIN COMBAT EFFECTIVENESS**

SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF MASTER OF MILITARY STUDIES

by

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AY 11-12

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*4 Apr 2012*

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## *Executive Summary*

**Title:** Leveraging Science and Technology to Improve Logistics

**Author:** Major Melissa Chestnut, United States Marine Corps

**Thesis:** There are important technological advances in logistical systems that must be leveraged to effectively support any future contingency and maintain combat effectiveness, while still reducing costs and minimizing US casualties.

**Discussion:** Many may argue that logistics is boring and tedious. Others may argue that logistics is an art within a science; complicated but doable. But no one can deny that logistics planning is a crucial aspect of war. The United States (US) has won many battles and significant wars in the past and the logistical throughput has been one of the main reasons for the success. The US is a formidable opponent regardless of the type of warfare (conventional or unconventional). The nation's military capabilities are the result of the military innovation that has occurred over the years and the advancements in technology, particularly in ground, maritime, and air logistics systems. The advancements in technology have been both evolutionary (inevitable) and revolutionary (remarkable). Regardless of how the advancements took place, the key point is advancements must continue to occur for the US to be successful in this ever changing global security environment. As the conduct in which wars are fought changes over the years so must the logistical methods in how wars are supported change. Science and technology have been on the forefront in logistical advances throughout history and will continue to ensure that the US military forces are the best supported forces in the world. Recent changes in warfighting, such as smaller units conducting distributed operations, have created a unique logistical challenge at the operational and tactical levels. In addition, fiscal constraints will force the US military to reprioritize programs of records. It is imperative that logistical systems are not moved to the back of the line because sustainment translates to combat effectiveness and sustainment is provided by logistics systems. By leveraging advancements in technology to improve logistics systems, the US military can continue to maintain its combat effectiveness in an ever changing security environment in spite of fiscal constraints.

**Conclusion:** An effective logistics system operating in an ever-changing environment should be adaptive rather than flexible, network-centric vice stove-piped, integrated, which is inherently interoperable, and sustainable. Separately these characteristics are difficult to realize, imagine trying to achieve them as a unit. Sense and Respond Logistics will provide the adaptability of the logistics systems. Integrated and improved information systems will pave the way for network-centricity. The sustainment portion is realized via the nation's strategic assets. The nation's strategic assets (e.g., ships and aircraft) are paired operationally at the correct time and place to support the troops on the ground.. Advancements in technology will bridge the gap between legacy logistics systems and future logistics systems by providing alternate means of support that will improve responsiveness and not only maintain but also increase combat effectiveness.

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## *Preface*

I wanted to look at the differences, if any, of logistical support provided for conventional versus unconventional war because of the changing global security environment and the US current economic disposition. To frame the paper, I found it easier to break up logistics support by using the levels of war. Even though the levels of war overlap, there are distinct logistical responsibilities required at each level depending upon where the logistical location of the support element. In addition, the tactical level determines if the strategic and operational level logistics planners were successful.

Dr. Richard DiNardo suggested this topic and after preliminary research I agreed that I would tackle the subject. At Dr. DiNardo's recommendation I consulted BGen David Reist, USMC (RET) on this subject. In my opinion he is a legend in the logistics community in the Marine Corps and it was an honor to receive assistance from him. He helped guide me toward new concepts in logistics that will improve support provided in this changing global security environment.

As I continued my paper, I realized what was prevalent was not the differences in how to support a conventional and unconventional war, but rather how advancements in science and technology can prepare the logistician to support combat operations regardless of the type of war.



## Introduction

As the old logistics tenet saying goes, “Amateurs study tactics, professionals study logistics.”<sup>1</sup> History has reiterated the importance of logistics during warfare and demonstrated, in many cases, how logistics has determined the success or failure of a war. Unfortunately, when discussing battles, the hierarchy of logistical efforts appear lower compared to tactics and strategy.<sup>2</sup> Although strategy and tactics determine how a nation fights a war, logistics determines the feasibility of the strategy and tactics.<sup>3</sup> In Henry Eccles’ book, *Logistics in the National Defense*, he states “sound logistics forms the foundation for the development of strategic flexibility and mobility.”<sup>4</sup> Put differently, a sound logistics plan allows the operational planners the flexibility to create supportable plans. The development of a successful logistics plan requires the merging of art and science. It is easy to mistake logistics for just a science, due to its quantitative nature. However, the decision-making by many logisticians has come from their creativity, intuition, insight, and mental flexibility when dealing with the uncertainty of battle.<sup>5</sup>

The changing global security environment has required the United States (US) military to adjust its warfighting technique. There is now a larger requirement for units to work as smaller units distributed over a large area. These distributed operations have created unique logistical challenges at the operational and tactical levels. These logistical challenges are not only evident due to the lengthened lines of communications, but also due to the increased difficulty in reaching troops in these dispersed locations. The impending fiscal constraints add another layer of difficulty to the changing security environment because less funds results in reduced resources. Another layer of difficulty imposed on the US military is the requirement to maintain the same level of combat effectiveness regardless of the changing global security environment

and future fiscal constraints. To maintain its combat effectiveness, the US military must ensure that solutions not only include weapons systems but also logistics systems. In fact, new weapons systems should only be considered if the logistical impact does not add an undue burden on the entire system.

As the Department of Defense's (DoD) budget is cut by \$487 billion<sup>6</sup> (Ewing, 2012) dollars over the next 10 years, military services should be very critical when prioritizing which programs to keep and which ones to cut. Those decisions should be primarily based on the ease of providing logistical support. The current US sentiment, as it relates to the military, predominantly revolves around two factors: 1) reduced military spending and 2) minimization of casualties. The current economic status of the US is fueling the first factor, while the unsettling realization that US military members are dying in a foreign country, fuels the second factor. Regardless of the type of mission the US military faces, logistics will more than likely determine its success or failure, and therefore should be the workable solution to address how the US military will maintain its combat effectiveness in a changing security environment. There are important technological advances in logistical systems that must be leveraged to effectively support any future contingency and maintain combat effectiveness, while still reducing costs and minimizing US casualties.

## **Background**

Despite the remarkable improvements in logistical concepts and systems, many of the US military's most important unsolved problems are logistical.<sup>7</sup> The current and future challenges of the global security environment only make logistical problems more difficult to solve. Before attempting to solve the impending logistical problems, logisticians must first get back to the fundamentals and ensure an understanding exists for the dominant influences over logistics, the

basic logistics options, and logistics at each level of war. Whether the United States (US) fights a large scale conventional war or many small unconventional wars, supporting the combat forces remains a requirement. The employment of unique ideas, coupled with improvements to processes, and innovations in technology will enable the US military to meet challenging logistical requirements. Advancements in technology have improved logistics responsiveness exponentially and provided troops with a level of comfort that persists and will endure, even if the battle takes place where planes cannot land or vehicles cannot traverse.

### Two Dominant Influences over Logistics

Logistics has two dominant influences: civilian and military. The civilian influences that dominate logistics stem from logistics' root in the national economy. Production efficiency governs the civilian authority's decision-making. In other words, the civilian influence focuses on producing the most goods while expending the least resources. Within the military realm of logistics, the ability to support and sustain combat operations effectively, dominates decision-making. This idea has helped to influence the US concerning stockpiling and prepositioning ships. Over the years these two differing criterion of logistics have required the civilian and military authorities to reach agreements regarding when, where, and how to employ forces with the ultimate goal of meeting national strategic aims.<sup>8</sup> Using the national end state as a premise, the military authority can demonstrate advancements in technology to convince the civilian authority that it is in the nation's best interest to invest in a technology that will improve efficiency, responsiveness, and continue to sustain combat forces regardless of their location.

### Three Basic Logistics Options

Moshe Kress, the author of *Operational Logistics: The Art and Science of Sustaining Military Operations*, describes three basic logistics options available to nations. The first basic

logistics option involves obtaining the needed resources at the battlefield or area of operations. In ancient times, water and food were essentially all the resources needed for battles. The armies found these resources along the way by foraging, looting civilians, or capturing the enemy's sources of water and food.<sup>9</sup> The second basic logistics option, carry the resources with the troops, became a requirement as the combat resources grew more diverse and specialized. Additionally, the improvement of the modes of transportation enabled troops to carry more supplies. The last basic logistics option requires the nation to ship the resources from the rear area and distribute them to the forces on the battlefield. The Industrial Revolution played a critical role in bringing this third logistics option to life, one example being the invention of the railroad.<sup>10</sup>

Nations employ all three logistics options with increased sophistication, due to the advancements in technology. Hence, instead of foraging or looting civilians, states establish contracts with host nations to fulfill option one, obtain resources at the area of operations. Nations also sign memorandums of agreement or understanding that allows the use of the neutral nation's roads, ports, and airports as part of the outside nation's distribution network. The Marine Air Ground Task Force (MAGTF) has the capability to perform a range of military operations. It can also sustain itself for a certain time frame. The size of the MAGTF will determine the longevity of sustainment. Therefore, carrying the resources with the troops remains an enduring logistics option for a MAGTF. On a smaller scale, special operating forces (SOF) carry many of their supplies with them as well. Last, as a modern military force the United States (US) primarily depends on the third option, ship resources from the rear. Primarily used for sustainment purposes, the third basic logistics option, is a complicated and integrated task largely dependent upon a nation's industrial capacity and the nation's financial and political means to support the requirements.

## Logistics At Each Level of War

The three levels of war are strategic, operational, and tactical. For the warfighter to receive the needed supplies and equipment, logistics has to cover all levels of war. The method in which the military clarifies the link between those strategic objectives and tactical actions reveal each level of war.<sup>11</sup> Events or actions within the three levels of war are not related to a particular command level or force type; rather the actions are defined as strategic, operational, or tactical based on their contribution to the overall strategic objective.<sup>12</sup> Even though three distinct levels of war exist, no line of demarcation divides each of the levels because of their interdependent and overlapping relationship. (See Figure 1) For example, operational and tactical actions by the military have positive and negative strategic implications. Strategic goals will help determine the operational and tactical actions. Based on the level of war the conduct of logistics will differ; however, the end state remains the same; resupply the warfighter by sustaining combat operations. Throughout history, advancements in technology have improved logistical support at all levels of war.

### *Strategic Level Logistics*

The strategic level of war is the level at which the nation determines the national security objectives and employs the nation's resources to accomplish them.<sup>13</sup> The substantial or limited capacity of a nation's industrial base, both government and commercial, exemplifies logistics at the strategic level. A nation's ability to project and sustain military power originates from the strategic level; it enables sustained military operations for prolonged periods of time and contributes to the outcome of wars. Logistics, while critical at all levels of war, obtains its strength and longevity from the strategic level. Therefore, if no overarching strategic plan for support exists, a harmful domino effect will occur eventually leading to ineffective and possibly

non-existent tactical level logistics. At the strategic level, a requirement exists for clearly defined, widely understood, and results focused processes to drive effectiveness across all organizations (e.g., joint, Service, interagency, and commercial).<sup>14</sup> These global processes are part of a strategic distribution network designed to store, pack, consolidate, and transport military material from the Continental United States (CONUS) or other locations outside of the area of operations to military units in support of combat operations.<sup>15</sup>

### *Operational Level Logistics*

The operational level of war ties the tactical employment of forces with the national security aim or strategic objectives. At the operational level of war the US military conducts and sustains military campaigns.<sup>16</sup> Even though strategic and tactical logistics overlap operational level logistics, the delivering of resources into the theater of operations simplifies the distinction of where operational logistics begins and strategic logistics ends. At the operational level of logistics, the disposition of forces on the battlefield, their individual missions, and their logistical capacity and requirements, are all inputs required to establish and maintain the logistics distribution network in theater. All these factors contribute to the fact that the operational level of logistics is by far the most vital and complicated level of logistics.

At the operational level of logistics not only does the strategic and tactical capabilities, processes, and requirements intersect, but also successful employment at this level requires the merging of art and science in order to obtain concrete and effective results on the battlefield. Operational level of war conveys the science of logistics through the use of tedious daily readiness reports submitted by lower level units to higher headquarters. These reports communicate the unit's current readiness level and assist the operational commander in overall logistical decision-making. The complicated operational logistical decisions that are more an art

than a science includes: determining the location and quantity of combat service support areas (CSSAs), deciding the feasibility of using prepositioned equipment and supplies, and establishing the logistical distribution network to facilitate sustainment. At the operational level of logistics, integration and coordination of national, Department of Defense (DoD), combatant command, Service and functional components, multinational, interagency, and Host Nation Support (HNS) capabilities must mesh with the Joint Force Commander's (JFC) tactical requirements.<sup>17</sup> According to Moshe Kress, the mission of operational logistics is to "set up the logistics system in the theater of operations, to operate this system and to forecast, analyze, and prioritize future demands for logistics assets – according to the operational objectives."<sup>18</sup> In the end, the ultimate goal is to support combat and non combat operations effectively by phasing resources into the theater of operations appropriately over time and space.<sup>19</sup>

### *Tactical Level Logistics*

The tactical level of war exists where combat units are employed. Many actions at the tactical level combine to achieve strategic objectives.<sup>20</sup> Primarily quantitative, logistics actions at the tactical level apply directly to combat forces.<sup>21</sup> The central logistical focus for higher headquarter elements rarely goes beyond the status of the lower level unit's readiness level. This does not mean that art does not exist at the tactical level; in fact, the tactical level is where creativity by logisticians excels as they have to adapt to changing tactical situations and support the combat forces based on their operational accessibility and logistical networks. The tactical level represents that part of the operational environment where outcomes are realized.<sup>22</sup> The tactical level is where the uncertainty and friction of war is most apparent. Actions in combat determine a need for certain resources at the tactical level, which subsequently have a logistical impact. While at the strategic level, logistics is relatively consistent and predictable; the opposite

holds true for the tactical level. Logistics at this level is not only unpredictable but also variable and even chaotic and greatly dependent upon the random outcome of the tactical battle.<sup>23</sup> The major challenge at the tactical level for the logistician is to create a predictable logistical support network at a level where unpredictability is the norm.

## **Advancements in Logistics**

Military innovation encompasses a vast array of concepts from, simple changes in standard operating procedures to complex advancements in technology. It has also attributed to advancements in military logistics throughout history. One can describe the advancements in technology as either evolutionary or revolutionary. The evolutionary changes are gradual, progressive developments that occur almost naturally or are inevitable, whereas the revolutionary changes are profound and make the new methods more powerful than the old.<sup>24</sup> In other words, evolutionary changes provide an impact over time, while revolutionary changes provide an immediate and significant impact and both impacts are due to advancements in technology. Advancements in logistics have occurred in ground, maritime, and air systems. The evolution of thought, tactics, and technology contributed to many logistical advancements, some of which attributed to revolutionary changes in logistics. Regardless of whether advancements in logistical systems were evolutionary or revolutionary, in all cases these advancements improved combat effectiveness.

### Ground Logistics Systems

The military uses Ground Logistics Systems to transport troops and equipment by roads, either paved or unpaved, or by rail. These logistics systems were as primitive as the horse and buggy and are now as advanced as the all-terrain Medium Tactical Vehicle Replacement (MTVR) truck. Regardless of the technology involved the end state remains the same; provide



the troops with needed supplies during combat operations. It was inevitable that supplying troops during combat would evolve from mere foraging off the land to bringing large supply blocks to sustain combat forces for an extended period, thus evolutionary.

One of the first ground logistics systems to revolutionize the concept of supplying troops from the rear was the railroad. Railroads proved to be of operational value in the 19<sup>th</sup> century because they were excellent at transporting troops and supplies to the start of a campaign in record time.<sup>25</sup> There were a few problems initially identified with the use of the rail systems; one particular problem stemmed from the numerous companies operating the lines, between whom synchronization and control rarely existed. The use of the standard track gauge – the distance between the two rails, helped reduce the friction caused by the multiple rail way companies. Of course in Europe, several countries continued to use a different gauge from their neighboring country to prevent them from invading by rail.<sup>26</sup> During the Civil War, the South was at a disadvantage because the majority of its railroads did not use the standard track gauge.<sup>27</sup> Another problem, bottlenecks, which occurred during unloading, slowed resupply efforts. The inclusion of wooden ramps and unloading the trains from the rear vice the sides, very simple solutions, helped to alleviate the problem.<sup>28</sup> Terrain and sovereign boundaries limited how far a train could go; therefore, the need for horses and wagons remained to transport supplies closer to the front lines and thus provide the tactical level logistics.

The motorized vehicle revolutionized the sustainment and resupply of troops in combat at the tactical level. According to John A. Lynn, the truck revolutionized logistics in World War II (WWII) by providing a new and extremely mobile link between the railhead and the combat forces in the field.<sup>29</sup> Without the 2.5 ton truck, campaigns during WWII would have stalled. The 2.5 ton trucks enabled the logistics tail to keep up with the troops.<sup>30</sup>

Evolutionary advancements of the truck not only included improvements to how the truck functioned (e.g., improvements to the braking and suspension systems) but also included an addition of vehicles performing different logistical missions. The 2.5 ton truck, or the Light Medium Tactical Vehicle (LMTV), evolved into the Family of Medium Tactical Vehicles (FMTVs), which have a 5 ton capacity. The FMTVs are variant vehicles based upon a common chassis that varied by payload and mission requirements. The FMTV contributed to the logistical effort with its superior reliability and off-road mobility. Evolutionary advancements in technology attributed to both of these improved capabilities of the FMTV. Other advancements in the wheeled vehicle include the Heavy Expanded Mobility Tactical Truck (HEMTT), the backbone of US Army logistics; the Palletized Load System (PLS), the line-haul vehicle of the US Army; and the M1070 Heavy Equipment Transporter (HET), which transports, deploys, recovers, and evacuates combat-loaded main battle tanks and other heavy tracked and wheeled vehicles to and from the battlefield.<sup>31</sup> The current ground logistics systems, though quite impressive, cannot reach all areas of the battlefield. In addition, depending upon the environment, many of their operators remain in constant danger while accomplishing their mission.

### Maritime Logistics Systems

The US Navy has been at the forefront of American logistics from its independence. Rhode Island was the first colony to propose a united navy for the colonies' joint protection, responsible to Congress.<sup>32</sup> Movement of troops and supplies by sea always has been the most resourceful means of transportation. Even to this day ships are used to carry most of the material consumed in war.<sup>33</sup> Many large ships can carry 60 to 90 days of food, enough fuel to cruise for 5,000 to 15,000 miles, and enough ammunition to respond to certain types of combat operations

for a considerable period. In essence, naval forces have enough built in logistics support to travel long distances and fight at a moderate rate without planning for additional logistical support other than oilers for refueling.<sup>34</sup> These combat logistics ships have the capability to replenish fleet units while underway.

Besides the advancements in size and capability of ships, the use of ships to support logistics at the strategic level has evolved from primarily military to primarily civilian. The requirement to use ships to support logistics will continue not only because the US DoD delivers about 95% of its international cargo by sea, but also due to the reduction of forward deployed bases.<sup>35</sup> As a result of fewer forward deployed bases the concept of sea basing evolved.

Sea basing is the expeditious deployment, assembly, command projection, reconstitution, and re-deployment of joint combat power from the sea, while providing continual support, sustainment, and force protection. Select expeditionary joint forces are supported through sea basing without a reliance on land bases within the Joint Operations Area (JOA).<sup>36</sup> The US military projects land combat power through a combination of forward operating bases, prepositioned equipment, and deployed resources in the US. Resources available on forward operating bases and prepositioned equipment are only relevant and ready if they are in the right location to respond rapidly to the crisis. The US sends an abundance of the deployed resources; however, these resources take time and require sea and air ports of debarkation for delivery.<sup>37</sup> To maintain a forward presence, project combat power ashore rapidly, and sustain a force from a sovereign location operationally independent of terrain, the US must depend on sea basing.<sup>38</sup>

The Navy's newest combat logistics ship, the T-AKE, is a dry cargo and ammunition ship that replaces the current capability of three different replenishment ships: Kilauea-class (ammunition ships), Mars-class (combat stores ships), and Sacramento-class (fast combat

support ships). The T-AKE has a primary and secondary mission. The primary mission requires the T-AKEs to provide the logistic lift to deliver cargo (e.g., food, fuel, repair parts, ammunition, and ship store items) to US and allied ships at sea. The secondary mission requires the T-AKEs to operate with a Henry J Kaiser-class (fleet replenishment oiler) as a substitute station ship to provide direct logistics support to ships within a carrier strike group. The civilian authority's goal of the T-AKE is to provide an effective fleet underway replenishment capability at the lowest life cycle cost, while the military authority's goal is to provide an auxiliary support ship that directly contributes to the ability of the Navy to maintain a forward presence.<sup>39</sup> Leveraging advancements technology will help both authorities achieve their goals.

#### Air Logistics Systems

The use of the aircraft to support logistics helped to achieve an essential element of the logistics systems: responsiveness.<sup>40</sup> The first use of Marine aircraft logistics support is traceable to the Banana Wars in the late 1920s, specifically the Nicaraguan campaign in 1927. To transport troops and supplies by air in support of combat forces, the Marines used the Atlantic Fokker tri-motor airplane, which seated 10 passengers and had a useful load capacity of 3260 pounds.<sup>41</sup> The use of this aircraft reduced the response time from Managua to Ocotal from about 10-21 days by ox cart or mule train to 1 hour 40 minutes by air.<sup>42</sup> This provided a revolutionary change in supporting logistics.

In World War II, due to Pacific theater operations, the need of rapid transport expanded. In response to the need, intra-theater air movement of personnel, equipment, and cargo became routine; however, the aircraft would not become a major factor in logistics support until after WWII.<sup>43</sup> The aircraft used to support military operations were essentially civilian aircraft with minor modifications. With increasing accuracy and availability of modern weapons, it became

apparent that the use of modified civilian aircraft in support of combat operations was not practical; however, a need remained for use of these aircraft. In order to exploit the logistical advantages provided by these aircraft two things occurred: 1) the US military built aircraft specifically to provide logistical support for the combat operations, and 2) the mission of operational support airlift would be re-directed to a relatively benign environment.<sup>44</sup>

Not until the 1960s and 1970s did the routine air movement of troops, equipment, and material achieve the level of responsiveness commonplace today. Military airlift capabilities have evolved from the payload of the Atlantic Fokker tri-motor to the 70, 847 pounds maximum payload of the C-141A Starlifter. The C-5 Galaxy is even more impressive with its 265,000 pounds maximum payload, a quantum leap in aircraft efficiency compared to the C-141.<sup>45</sup> The C-5 represented significant advancements in technology as it entered service in late 1969. A few examples of advancements to the C-5 include aerodynamics, hydraulics, and automatic flight controls.<sup>46</sup> The military airlift capability provides logistical support at the strategic and operational levels.

At the tactical level, air drop or aerial delivery, is one type of logistical support provided by the aircraft. Two fundamental advantages of aerial delivery are that the air drops allow troops to maneuver and negotiate their mission successfully regardless of the terrain, and the air drops provide a capability to deliver much needed supplies to combat troops in remote locations.<sup>47</sup> The British used air drops to resupply long range penetration troops during the China-Burma-India (CBI) campaign in WWII.<sup>48</sup> Recent historical examples of the US military using air drops include Bosnia, Kosovo, Iraq, and Afghanistan.<sup>49</sup>

Most of the disadvantages to aerial delivery relate to where the supplies are dropped. The increased potential for an enemy force to jeopardize the retrieval mission exists, because air

drops zones are marked in advance. Air drops have resulted in the scattering of pallets over a sizeable area, which increases the enemy's chances of conducting an ambush on the ground troops. Units have sustained heavy losses due to this practice by Japanese forces in the CBI campaign as well as by the Vietcong during the Vietnam War. Even though most air drops occur at high altitudes, certain missions require low altitude air drops, which increase the chances of an enemy attack on the aircraft. One last disadvantage of air drops is that sometimes air delivered supplies are lost in no man's zones (i.e. land neither occupied by the enemy or allies) or even worse, enemy territory. The obvious implication of this last disadvantage is the requirement to reschedule more air sorties for replacement supplies, which results in loss of time and money.<sup>50</sup> In summary, one can deduce that the largest error when it comes to aerial delivery is the release point calculation, or that point in time and space when the delivery system releases the package.

Basing the release point on a wind estimate vice actual wind conditions upon release resulted in the inaccurate release point calculation. Advancements in technology have resulted in probes that can acquire near real-time wind measurement, known as ram-air technology. The ram-air technology allows for the tracking of the wind direction, which automatically updates the release point, altitude, and flight plan of the cargo systems. The combination of the ram-air technology and auto-piloting capability has a revolutionary impact on the method of resupplying ground troops. These systems radically improve the accuracy of aerial delivery by landing an unguided cargo pallet within 400 meters of the assigned drop point, when released from 25,000 feet.<sup>51</sup> The addition of the global positioning system (GPS) to aerial delivery allowed for the use of the more recent term "precision aerial delivery" because of the improved results. The US Marine Corps started using GPS-guided ram-air parachutes in 2004, which resulted in a one ton load landing within 70 meters of its designated target point.<sup>52</sup>

Land logistics systems revolutionized logistics with the motorized vehicle providing improved logistics support at the operational and tactical levels. Ships continue to bring the strategic assets to the fight as well as provide operational and tactical level logistical support. Air logistics systems improved responsiveness exponentially and provide the strategic, operational, and tactical level logistics support. Even though each logistics system (e.g., ground, maritime, and air) has its unique advantages, no one method of logistical support is more important than the other. Their functions overlap with one another just as the levels of war overlap. They all tie into a larger logistical network and have improved logistical capabilities throughout history, due to advancements in technology.

## **Science and Technology in Logistics**

The advancements in logistics at times have come to fruition by simple evolution and at other times by revolutionary breakthroughs. Many of the advancements occurred because of the normal military culture of innovation. As the warfighters changed how they fought, the logisticians had to change how they supported the warfighter.

When the US military goes into a fight it has the weight of the US infrastructure behind it. Over the years due to innovation in science and technology, the US has become a formidable force in conventional battle. Improvements and additions to the modes of delivery and the concept of distribution have increased the warfighter's confidence in the logistics system. The current manned modes of delivery include ground (e.g., cargo truck), maritime (e.g., watercraft or ship), and air (e.g., helicopter and fixed wing).<sup>53</sup> These modes of delivery have been quite successful in conventional wars and unconventional wars when combined with improved military applications and new thought processes. In preparing for the most likely wars or conflicts in the future (e.g., unconventional), reduced manpower and resources with increased

capacity and capability will be the norm. Unmanned modes of delivery will help achieve this goal.

Unmanned modes of delivery are currently under development but also fall within the three broad categories of ground, maritime, and air.<sup>54</sup> Along with the recalibration of the joint force, according to the 2012 National Defense Strategic Guidance, science and technology must be leveraged to meet the subset missions of “counter terrorism and irregular warfare; deter and defeat aggression; maintain a safe, secure, and effective nuclear deterrent; and defend the homeland and support civil authorities.”<sup>55</sup> Another aspect of unmanned modes of delivery is the use of robotics, defined by Merriam-Webster’s online dictionary as a “technology dealing with the design, construction, and operation of robots in automation.”<sup>56</sup> A few systems that currently use robotics are the Joint Precision Aerial Delivery Systems (JPADS) and the different robots used to support Explosive Ordnance Device (EOD) personnel.

Effectively supporting future battles will require logisticians of all military services to leverage the innovative solutions available to meet the operational needs of the Combatant Commander or JFC. Other innovative solutions include radio frequency identification (down to the component level), sense and respond logistics, and improved logistics information systems. Incorporating the above innovative solutions into a functioning logistics network will improve survivability and increase the adaptability of sustainment support.<sup>57</sup>

### Unmanned Logistics Systems

#### *Ground*

The heart of logistics is the distribution network. Delivering needed supplies using manned logistics vehicles requires manpower. Unmanned logistics systems have the added benefit of not only decreasing casualty rates but also decreasing logistics costs. Unmanned logistics systems are devices with specific components that permit execution of required



functions without the need for an operator to be physically present or in direct contact with the onboard control system.<sup>58</sup> The majority of unmanned ground system applications perform repetitive, hazardous, or complicated work. The US military currently leverages ground, maritime, and aerial unmanned systems to meet operational needs.<sup>59</sup>

The Marine Corps Warfighting Laboratory conducted testing in May 2011 on at least two unmanned ground vehicles. One was an unmanned MTRV truck being tested specifically to target reducing the number of Marines who drive outside the wire during resupply convoys. Sometime in 2012 a culminating experiment will take place. The Marine Corps is also developing a Ground Unmanned Vehicle Support Surrogate. It is a 3,000 pound cart that transports up to 1,200 pounds. This program will assess how unmanned vehicles can assist dismounted Marines by carrying supplies such as food and water.<sup>60</sup>

The Defense Advanced Research Projects Agency (DARPA) has developed a Legged Squad Support System (LS3) to help lighten the load of the combat troop. The LS3 is a highly mobile, semi-autonomous legged robot that stands up, lies down, and follows a leader carrying 400 pounds of a squad's gear. (See Figure 2) In addition, the LS3 functions as a mobile auxiliary power source that allows troops to recharge batteries (e.g., radios and handheld devices) while on patrol. According to a DARPA news release dated February 2, 2012, the LS3 will undergo extensive testing over the next 18 months to test and validate its ability to carry 400 pounds on a 20-mile march in 24 hours without refueling. They also plan to add new features that enable squad members to speak commands to the LS3 such as "stop," "sit," or "come here." In the end, the LS3 will serve as a pack mule and respond like a trained animal.<sup>61</sup>

The US military has several unmanned ground logistics vehicles currently in development or in service that perform additional capabilities, besides logistics, depending on

the type of unmanned ground vehicle (UGV). For example, the R-Gator provides reconnaissance, the CaMEL provides fire power, the Porter provides explosive ordnance support (Porter), and the Seekur provides perimeter security.<sup>62</sup> See Table 1 for detailed information on each UGV and its unique attributes. These unmanned vehicles are advancements in technology designed to help the warfighter on the ground, providing operational and tactical level support.

### *Maritime*

Most maritime unmanned systems have missions that focus on mine countermeasures (MCM), anti-submarine warfare (ASW), electronic warfare (EW), surface warfare, maritime security, reconnaissance, and surveillance. This includes the unmanned undersea vehicles (UUVs) and the unmanned surface vehicles (USV). The Navy's Master Plan documents for each vehicle clearly state separate and distinct missions for each vehicle type in relation to providing logistical support. For the UUVs, payload delivery is a distinct logistical mission. The objective is to provide a covert or surreptitious method of delivering logistical support to a variety of other mission areas to include MCM, ASW, and SOF support.<sup>63</sup> According to the US Navy's Unmanned Surface Vehicle (USV) Master Plan, the USV provides logistical support to SOF. In fact, the logistical support is a secondary mission after the Intelligence Surveillance and Reconnaissance (ISR) mission. The larger USV could be pre-positioned at a certain location and provide logistical support when called.<sup>64</sup>

### *Air*

The idea of employing unmanned aircraft systems (UASs) in support of military operations is not a new initiative; however, utilizing them for logistical purposes is becoming more of a reality. Two French brothers invented the aerial balloon in 1783. Within four months of the aerial balloon's invention, military theorists publicly expressed their desire to employ the

aerial balloon as an instrument of war. The potential military uses of the aerial balloon included reconnaissance in land and sea operations and long range signaling.<sup>65</sup> Since then the UAS has evolved to a much more capable and complex system that can perform various tasks including relaying radio signals, surveillance of enemy activity, target designation and monitoring, elimination of unexploded bombs, and the location and destruction of land mines.<sup>66</sup>

When a high threat to ground logistics vehicles exists, the US military can use unmanned aerial vehicles (UAVs) to provide logistical support. The use of unmanned aerial vehicles to provide logistical support results in a faster delivery time of ammunition, food, water, medical supplies, or critical parts compared to ground logistics vehicles. Deployed in conjunction with the precision aerial delivery systems, the cargo UAV has the potential to reduce the risk to human life, reduce the logistics footprint in the theater of operations, and improve logistics effectiveness and efficiency. The US military can develop the same manned platforms available--helicopters, fixed-wing aircraft, and blimps--as unmanned in support of logistical missions.<sup>67</sup>

Even though there are not many UAVs developed for logistical purposes, recently the US military has taken an increased interest in using this technology for logistical functions. According to open source media, the Marine Corps is currently testing an unmanned helicopter that can carry three short tons or 6,000 pounds of supplies to troops in remote and dangerous regions in Afghanistan.<sup>68</sup> (See Figure 3) On January 6, 2012, the Army released a request for information (RFI) on the Federal Business Opportunities website for information on a Cargo Unmanned Aircraft Systems (Cargo UAS). The US Army wanted information on future concepts for the Cargo UAS utility seven – 10 years from now. One concept in particular that interests the US Army is the ability for the Cargo UAS to carry between 5000 and 8000 pounds of all classes of supplies internally and externally.<sup>69</sup> The current Cargo Unmanned Aerial or

Aircraft System (CUAS) provides a solution to deliver more customized ammunition, supplies, fuel, water, or weapons packages in adverse weather conditions over harsh terrain as required. However, the ability to avoid obstacles at a landing site and trained CUAS operators with a certain level of control over flight parameters are requirements not currently fulfilled.<sup>70</sup>

In October 2011, the Office of Naval Research (ONR) began developing an Autonomous Aerial Cargo/Utility System (AACUS). The AACUS represents a considerable leap over both present-day operations and more near-term CUAS development programs because the AACUS focuses on autonomous obstacle avoidance and unprepared landing site selection: two key disadvantages to the current CUAS program. Developed with an open architecture framework, the AACUS will have the ability to be used across different air vehicle platforms.<sup>71</sup>

#### Automatic Identification Technology (AIT)

Automatic Identification Technology (AIT) is defined as “a family of technologies that improve the efficiency, precision, and timeliness of material identification and data collection.”<sup>72</sup>

In other words, AIT has provided the user with instantaneous information of equipment to include: its origin, its destination, its current location, and unique identifying markers.

Challenges faced by the DoD involve the lack of asset visibility and transportation process inefficiencies between nodes in the supply chain. As stated earlier, logistics also has a psychological impact on the warfighter; thus, possessing the ability to build a responsive, cost effective capacity that provides required resources to the warfighter is critical to improving customer confidence in the DoD logistics process.

Examples of AIT media devices include passive and active radio frequency identification (RFID), bar codes, smart cards, magnetic stripe cards, and optical memory cards (OMC).<sup>73</sup>

Employing these technologies in tandem produces a hands-free, accurate, reliable, and efficient

end-to-end supply chain enterprise. Based on US Transportation Command's (USTRANSCOM) DoD AIT Implementation Plan for Supply and Distribution Operations the DoD is currently on track in the employment of AIT devices. The DoD AIT plan is implemented in fiscal years (FY) and has three phases or spirals. Spiral I introduced passive RFID and closed out at the end of FY09.<sup>74</sup> Spiral II, which closes out at the end of FY12, introduced active RFID, premium AIT (e.g., cellular, satellite, and sensor technology), and item unique identification (IUD).<sup>75</sup> The end of FY12 is the current publishing deadline for Spiral III with the implementation planned for FY 13-15.<sup>76</sup>

### Sense and Respond Logistics

Sense and Respond Logistics (S&RL) is the revolutionary network-centric school of thought that facilitates Joint effects-based operations and provides exact and improved responsive support. It is heavily dependent upon adaptive, self-synchronizing, and changing practical and physical processes.<sup>77</sup> Key aspects of S&RL are its ability to predict and anticipate requirements so that actions are coordinated and integrated to support military operations across all levels of war.<sup>78</sup> The method of building large stockpiles of equipment and supplies before a ground or air war could begin is slowly becoming an issue of the past. The impending constraint is due largely in part to the nation's own fiscal constraints, an enemy not associated with a particular state, and decreased access to forward operating bases.<sup>79</sup> In addition, a mission could be assigned in which smaller forces are required to quell an insurgency and leave immediately. Stockpiles will hinder a quick withdrawal from the area. Logistics support of the future will need to sense when a certain supply item is required and respond within a given time frame. This capability ensures the unit receives the correct support at the right time.

The stove-pipe logistics systems made it hard for the DoD to achieve network-centricity. Advancements in technology and changes in military logistics concepts will help logistic systems achieve precision. At the unit level, combat service support battalion planners should use sense and respond to increase the effectiveness and responsiveness of logistics support.<sup>80</sup> With military operations becoming more non-linear, distributed, and adaptive, the support infrastructure has to adjust as well. S&RL is adaptive rather than flexible. Flexible logistics, although effective can only be stretched so far, where as adaptive logistics will adjust and change based on the requirement. In an ever-changing combat environment, there exists an increased need for logistics systems to adapt. In addition, an adaptive logistics capability will help avoid cumbersome surpluses. The concept of sense and respond is not new; however, logisticians must adopt sense and respond principles as a separate logistics tenet of its own.<sup>81</sup> It needs to become the new buzz phrase, taught in logistics schools, and practiced during training. According to an article written by Michael Hammond in the then named *Army Logistician*, in the Battalion Support Brigade (BSB), the sense and respond concept is evident in three ways:

1. Logistics planners and unit commanders must design systems so that all personnel understand their roles.
2. Key planners in the BSB must sense in real time what is happening on the battlefield and respond accordingly.
3. The BSB planners must dispatch assets in response to changes on the battlefield.<sup>82</sup>

In other words, if a logistician understands the unit's role in the logistics pipeline and possesses the ability to determine the needs of the combat troops as close to real time as possible, the logistician will be able to respond quickly in an unpredictable and ever-changing battlefield.

One key lesson learned in studying information technology management is before applying technology to a process, it is imperative that the process is well-defined, understood, and effective. This technique allows for the injection of technology where technology will

improve, not hinder the process. In the case of S&RL, once the logistics community accepts it as a tenet of logistics, innovative technological solutions can be developed to improve its effectiveness and efficiency. For example, sensors can be added to fuel tanks to track their current level. Logistics support units would then respond based on the data collected from the sensor. S&RL technology benefits distributed forces because it increases the probability that units only receive required items.

### Logistics Information Systems

The quantitative nature of logistics requires an enormous amount of data to be collected, processed, and stored so that it can be used to support combat operations.<sup>83</sup> In the past, logisticians recorded data in ledgers and logbooks, but due to advancements in technology, logisticians now record data in automated information systems. The science aspect of logistics has to do with analyzing the health or readiness of an organization based upon the current status of the organization's organic assets. All this information can be overwhelming for a commander; thus, a need to collate the logistics information in such a way that it is useful to the commander's decision-making process exists.

The current Marine Corps logistics information system that assists a commander in making a decision is the Marine Corps Equipment Readiness Information Tool, better known as MERIT. MERIT is a web-based ground equipment readiness management decision support tool that pulls data from supply and maintenance management legacy systems used by the Marine Corps. It graphically depicts the current readiness posture and detailed maintenance and supply information for all Marine Corps readiness reportable assets.<sup>84</sup> The key aspects of MERIT are that it is an adaptable, versatile, and scalable logistics information system that will be able to import from planned future Marine Corps logistics systems and non-Marine Corps automated

information systems.<sup>85</sup> As the US military develops advanced logistical information systems, the ability of the system to integrate with other systems should be listed as a key performance parameter in the capabilities development document.

The Army and the Marine Corps have implemented the Global Combat Support System (GCSS), referred to as GCSS-Army and GCSS-MC respectively. According to Marine Corps Systems Command, when fully implemented, “GCSS-MC will enable streamlined processes and provide accurate, near real-time visibility of data.”<sup>86</sup> The resulting enterprise-wide visibility of data will allow logistics planners and operators to make decisions about their supply network based on accurate information GCSS-MC provides a capability in which the supply, maintenance, and finance personnel can all perform their duties in one system.<sup>87</sup> Prior to GCSS-MC, the logistics and finance personnel performed their duties using multiple systems that sometimes did not interact properly with one another. Network-centric, integrated, and adaptive products require network-centric, integrated, and adaptive information systems to marry up with them. The move toward a state-of-the-art logistics functionality will allow the US military to maintain a lethal and agile combat capability.

## **Recommendations**

If the US military wants an effective logistics system that can operate in an ever-changing environment, the system must have the following characteristics: adaptive rather than flexible, network-centric vice stove-piped, integrated, which is inherently interoperable, and sustainable. Advancements in technology bridge the gap between legacy logistics systems and future logistics systems. For example, unmanned modes of delivery provide an operational and tactical logistical advantage by affording the commander the opportunity to supply forces in hard to reach or high risk areas on the battlefield. At a minimum, before adding advanced technology to any logistics

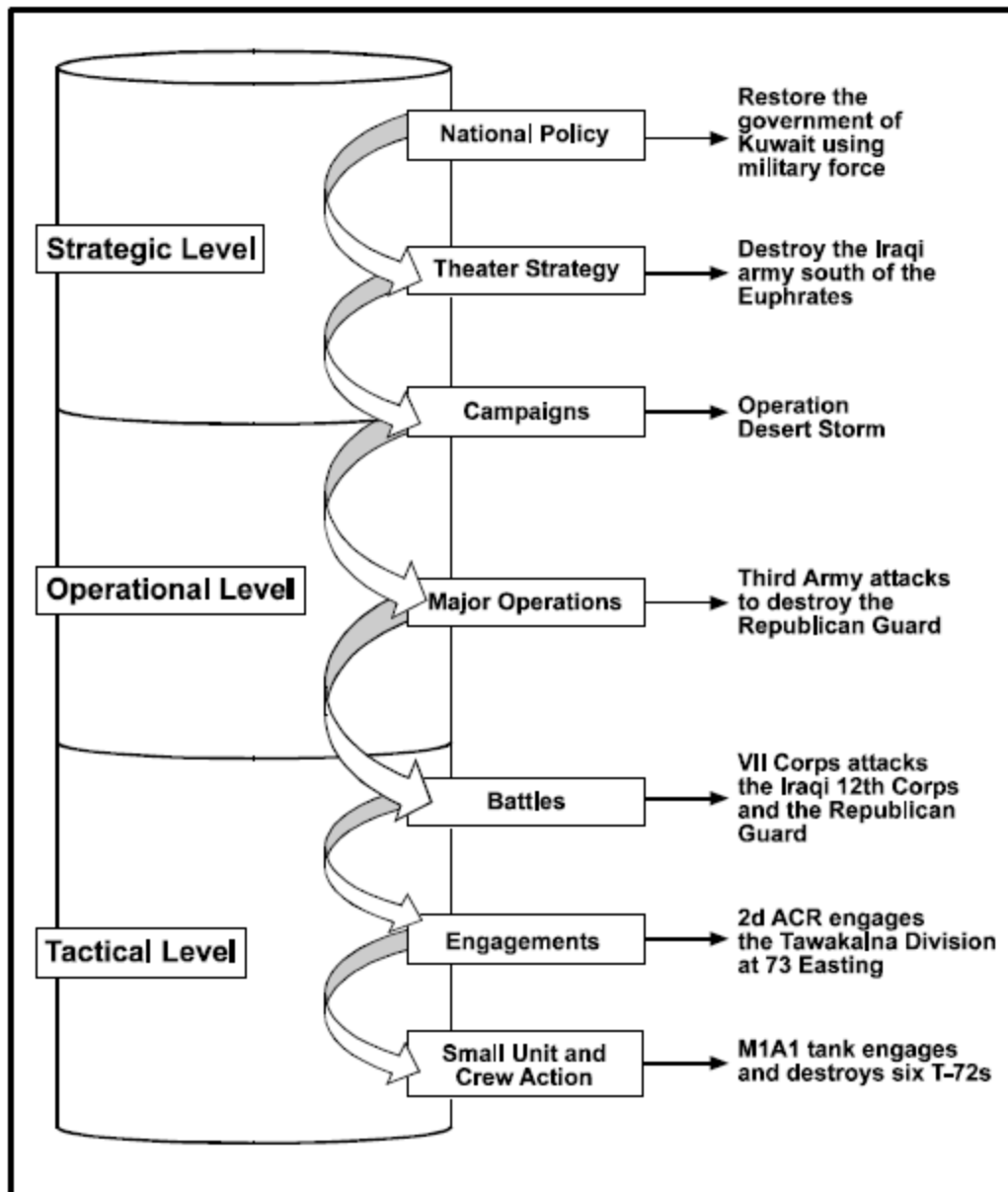


system, the system must have a well-defined and functioning process and the technology should improve not hinder the process.

## **Conclusion**

When faced with the challenges of supporting combat troops logistically the same problems exist regardless of the type of war. By leveraging the advancements in technology discussed in this paper, current logistical limitations can be reduced and eventually eliminated. AIT provides the commander with the ability to track the location of supplies on the battlefield. S&RL ensures the commander only receives needed supplies at the right time. And an integrated logistics system links logistical requirements at the component level and supports the commander in the decision-making process.

The unmanned logistics systems have the added benefit of minimizing casualties and eventually reducing costs. These systems reduce costs because they can be used for multiple missions and since they are unmanned, manpower is reduced. Of course, it should be understood that initially the unmanned logistics systems will be expensive due to the cost of the technology, the requirement to train personnel on the system, and the initial contract support required to maintain the system. These initial costs should not sway the military from continuing in that direction because an unmanned logistics system that carries supplies and conducts intelligence and surveillance is much more cost effective than two separate systems that perform each mission. The US military's end state, 'increased combat effectiveness,' is achieved through the sustainment of combat troops and this sustainment is realized by leveraging advancements in science and technology to improve logistics systems.



**Figure 1 Levels of War**

*Source:* Department of the Army. *Operations*, FM 3-0 (Washington, DC: HQ Department of the Army, 2001)









**Figure 2: Legged Squad Support Systems (LS3)**



*Source:* Defense Advanced Research Projects Agency (DARPA),  
<http://www.darpa.mil/NewsEvents/Releases/2012/02/07.aspx>



**Figure 3: K-MAX, USMC Cargo UAS**

*Source:* MILPAGES, <http://www.milpages.com/blog/299339>

Name	Unique Capability	Log Specs	Picture
<p>Carry-all Mechanized Equipment Landrover (CaMEL)</p> <p>[Type: Medium tracked transport and armed UGV]</p> <p>[Status: Development completed]</p> <p>Trial platform in load-carrying configuration planned for 2011's US Army's Joint Warfighting Experiment</p>	<p>Planned to be able to be carried in a High Mobility Multipurpose Wheeled Vehicle (HMMWV or Humvee) and controlled from an operator station within the Humvee. Designed to be a load carrying vehicle; is also weaponized (mount is equipped with a .50 caliber machine gun); all-terrain multi-purpose.</p> <p>The vehicle has a hybrid powerplant in that it a battery is used until it becomes depleted when it is recharged using the primary diesel engine with a 9.0 litre tank and a secondary 4.1 litre tank to provide 36 h of run time.</p> <p>Used for EOD support by Israel.</p>	Max Payload = 544 kg	
<p>Multifunctional Utility/Logistics &amp; Equipment (MULE)</p> <p>[Type: Large Wheeled Multi-Purpose UGV]</p> <p>[Status: MULE ARV-A(L) is in development]</p>	<p>The MULE has 6 wheels that are individually attached to separate articulated axles that can adjust wheel position in all three dimensions. This creates a type of independent suspension that allows the vehicle to negotiate irregular surfaces such as low walls. If one of the wheels or axles is disabled, the vehicle can adjust its centre of gravity to drive on five (or even as few as three) wheels.</p> <p>The MULE includes three variants: Armed Robotic Vehicle - Assault (Light), Transport and Countermine.</p>	Two infantry squad loads ~ 970kg	
<p>Porter</p> <p>[Type: Medium wheeled logistics, reconnaissance and explosive ordnance disposal UGV]</p> <p>[Status: still in development]</p>	<p>Designed to be either tracked or wheeled;</p> <p>Planned modes of operation include 'follow me' or operator Control</p>	Medium load of 270 kg	<p>Load carrying</p>  <p>Reconnaissance</p> 
<p>Robotic Gator (R-Gator)</p> <p>[Type: Large Wheeled Logistics and Patrol UGV]</p> <p>[Status: Research and Development ongoing]</p>	<p>Built on a combat-proven military utility vehicle platform and is designed to serve numerous important roles, including acting as an unmanned scout, perimeter guard, pack/ammunition/supply carrier for soldiers, marines and airmen.</p>	<p>Max payload = 363 kg</p> <p>Max towing capacity = 680kg</p>	
<p>Seekur</p> <p>[Type: Medium Wheeled Patrol and Logistics UGV]</p> <p>[Status: in service]</p>	<p>Designed as a load carrier as well as fulfilling airport and perimeter security, advance scout and inspection roles.</p> <p>Designed as an autonomous vehicle but can be tele-operated</p>	<p>Payload = 70 kg on flat, 50 kg on 20% grade, 100 kg saddle bagged</p>	

<p>Squad Mission Support Systems (SMSS)</p> <p>[Type: Large Wheeled Logistics UGV]</p> <p>[Status: Five vehicles have been built and test units have been delivered]</p>	<p>Multi-mission vehicle targeted at light forces and special operations forces;</p> <p>The key concept is to reduce weight carried by the individual soldier but the option remains to eventually create a family of vehicles such as assault, medical, mortar and communications variants;</p> <p>Control of the vehicle is expected to range from manned or tele-operated to a high level of autonomy</p>	<p>Max payload = 544kg</p>	
<p>TerraMax</p> <p>[Type: Large Wheeled Logistics UGV]</p> <p>[Status: In Development]</p>	<p>A modified version of Oshkosh's manned 66 12,600 kg Medium Tactical Vehicle Replacement (MTVR);</p> <p>The vehicle retains most of the design and features of the MTVR including all wheel drive, TAK-4 independent suspension and central tire inflation, which allows for adjustment according to load.</p> <p>The TerraMax autonomous controls and sensors are designed to be applicable to a range of manned vehicles and include vision system, light detection and ranging sensor, GPS/inertial measurement unit system, navigation computers and controls for brakes, steering and transmission.</p>	<p>Max Payload = 5000 kg</p>	

**Table 1: Unmanned Logistics Vehicles**

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<sup>66</sup>Reg Austin, *Unmanned Aircraft Systems: UAVs Design, Development, and Deployment*, (Reston, VA: John Wiley & Sons Ltd, 2010), 2.

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